



# Wood heating & health impacts

Jared Ulmer

Climate & Health Program Manager

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## General health statements about all combustion fuels

- Regardless of fuel source, it is healthy for everyone to have affordable access to the resources needed for staying sufficiently warm (or cool)
- Combustion emissions from any fuel have harmful health effects

# Key points about wood combustion & health impacts

1. Fine particulates are the main cause of health impacts from wood combustion
2. Any amount of combustion emissions is associated with negative health impacts
3. Residential sources account for most wood combustion emissions
4. Even the most advanced residential wood combustion generates more harmful emissions than residential oil/gas combustion
5. Home weatherization, cold-climate heat pumps provide health co-benefits

# Emissions of health concern from wood combustion

- **Particulate matter** – tiny solid & liquid particles
- **Gases**
  - Carbon monoxide
  - Sulfur oxides
  - Nitrogen oxides
- **Hazardous air contaminants**
  - Volatile organic compounds (ex., Benzene, Formaldehyde)
  - Polycyclic aromatic hydrocarbons (ex. Naphthalene)
  - Heavy metals (ex., Arsenic, Lead)



# How do we know about the health impacts of air pollution?

**Epidemiology studies** – statistically analyze differences in health outcomes comparing people with different amounts of air pollution exposure

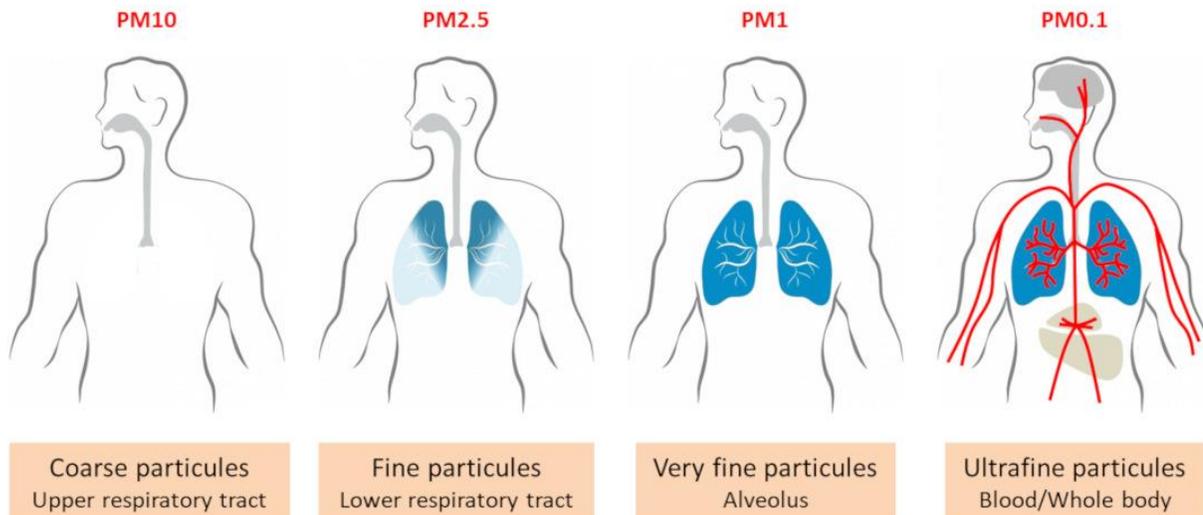
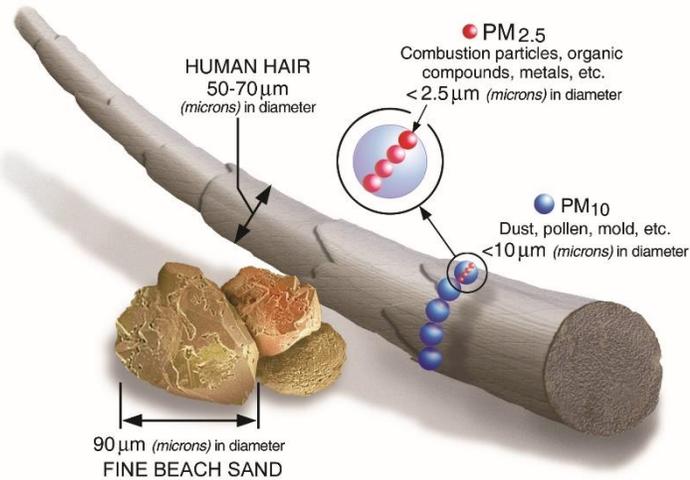
- Acute events (ex., wildfires, traffic bans)
- Occupational exposures
- Long-term (chronic) exposure

## **Human/animal lab studies**

- Observe symptoms & health impacts
- Quantify dose-response relationships
- Assess biological mechanisms



# Fine particulate matter (PM<sub>2.5</sub>) and health impacts



## Potential health impacts:

- Irritation of eyes, nose, throat, lungs
- Shortness of breath, reduced lung function
- Asthma attacks, bronchitis, COVID-19 severity
- Irregular heartbeat, heart attacks
- Early death

## PM<sub>2.5</sub> is particularly harmful for:

- People with pre-existing breathing and heart problems
- Children, older adults, pregnant women

# National Ambient Air Quality Standards (NAAQS)

## PM<sub>2.5</sub>, yearly standard

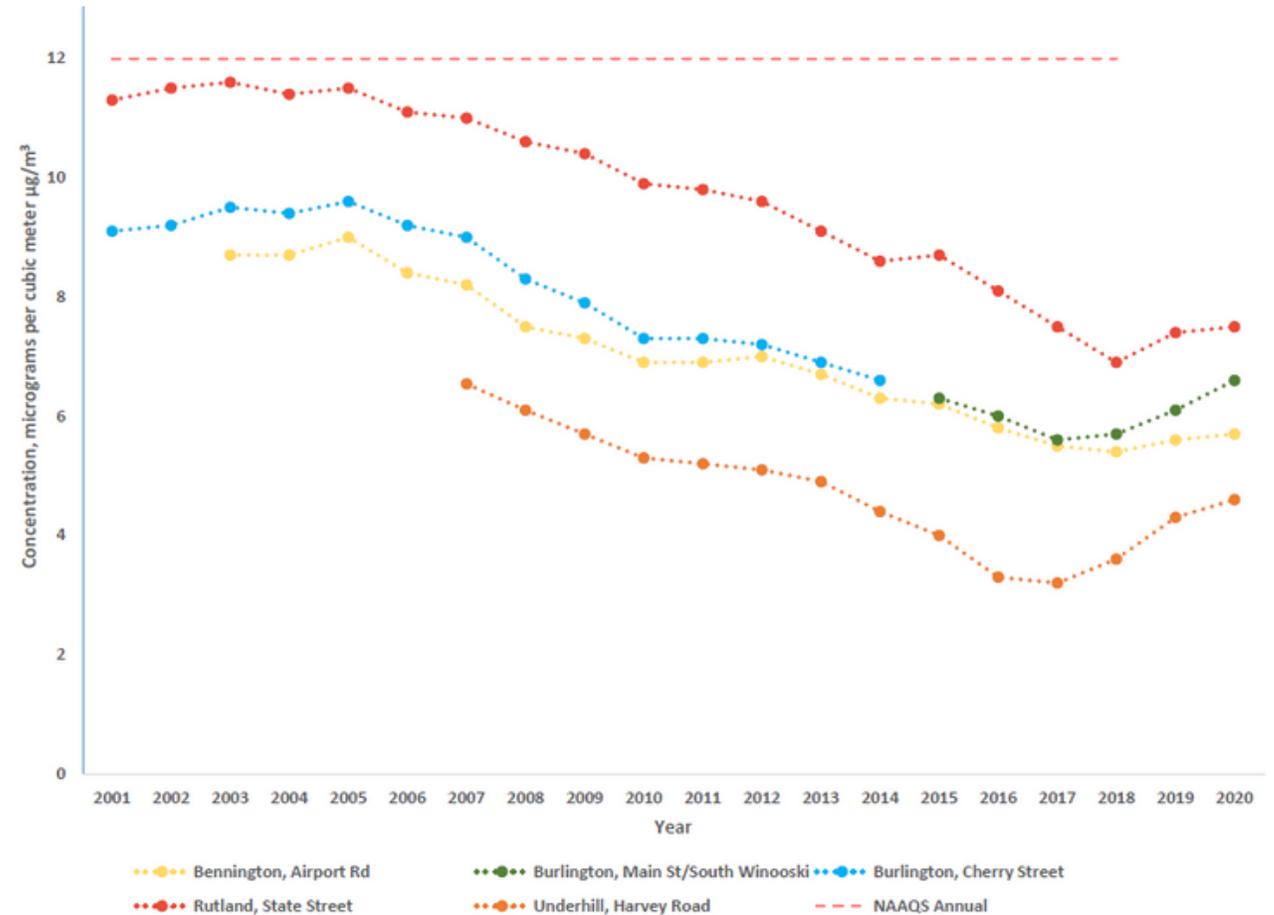
Source: Vermont Department of Environmental Conservation

## Fine Particulate (PM<sub>2.5</sub>) Annual Average



Annual averages for 2001-2014 are based on filter-based samples collected every three days. Annual averages for 2015-2020 are based on continuous one-hour averages. Annual averages presented for each year are the average of EPA design values\* for the previous three-years.

Reference: EPA Design Value Report AMP480 8/24/21



\*Annual mean, averaged over 3 years

# National Ambient Air Quality Standards (NAAQS)

## PM<sub>2.5</sub>, yearly standard

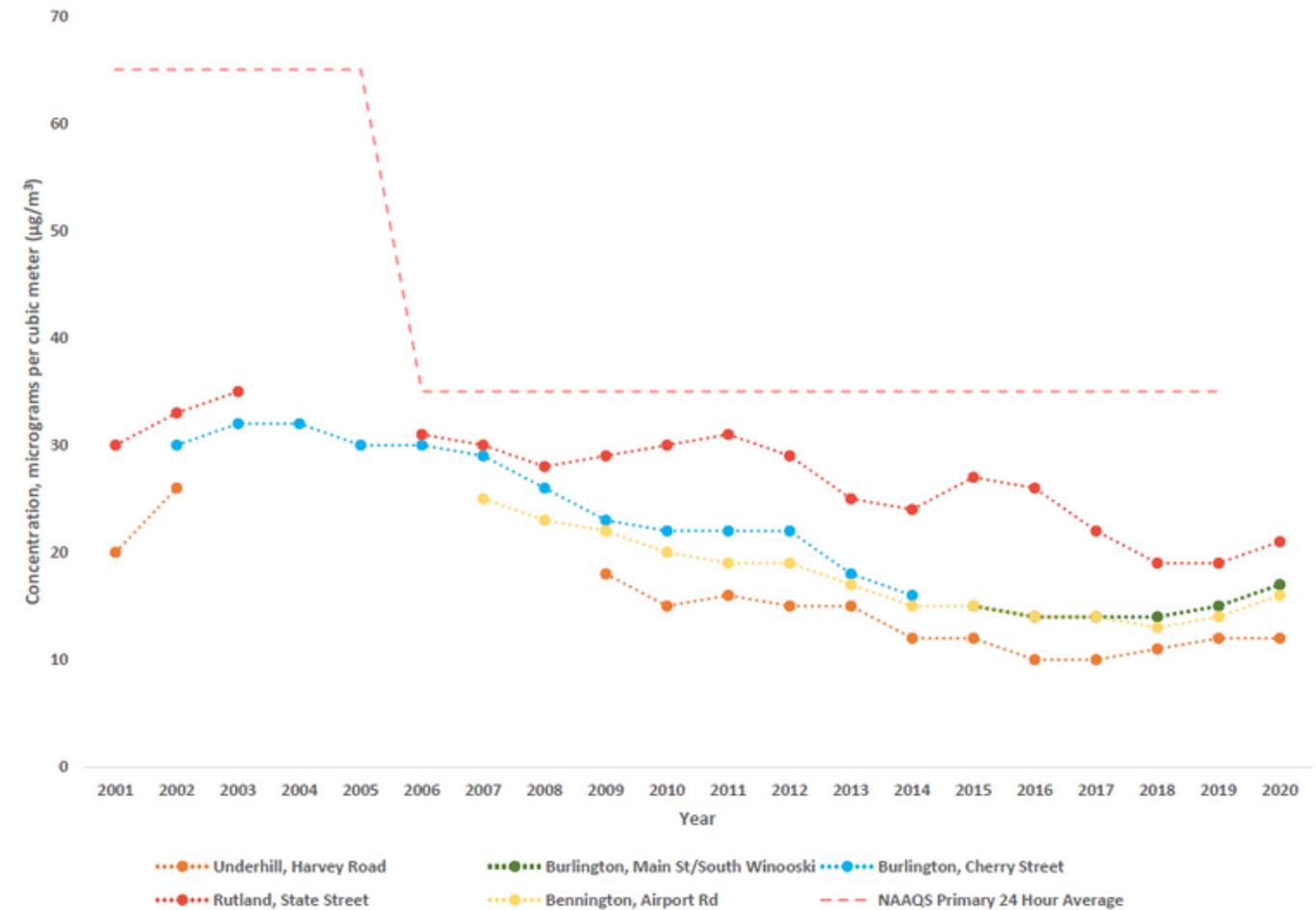
Source: Vermont Department of Environmental Conservation

## Fine Particulate (PM<sub>2.5</sub>) 24-Hour Average



Twenty four-hour averages for 2001-2014 are based on filter-based samples collected every three days. Twenty four-hour averages for 2015-2020 are based on continuous one-hour averages. Twenty four-hour averages presented for each year are the average of EPA design values\* for the previous three-years.

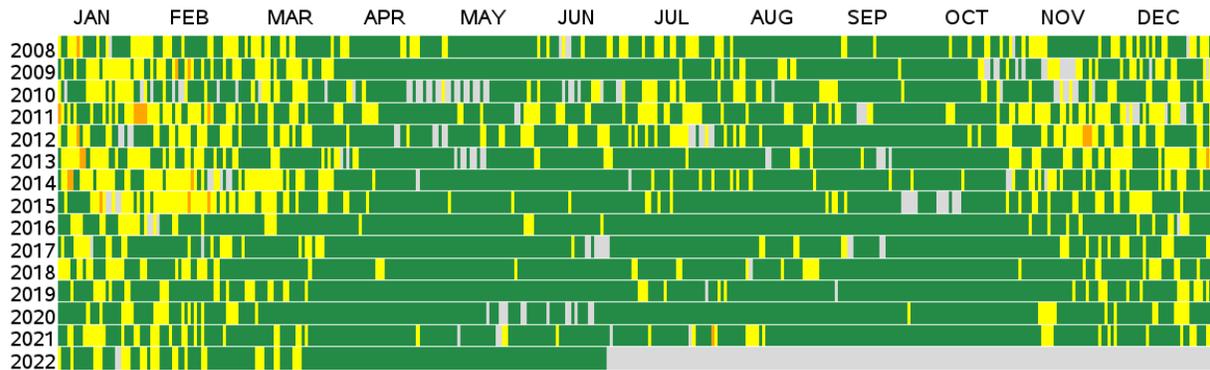
Reference: EPA Design Value Report AMP480 8/24/21



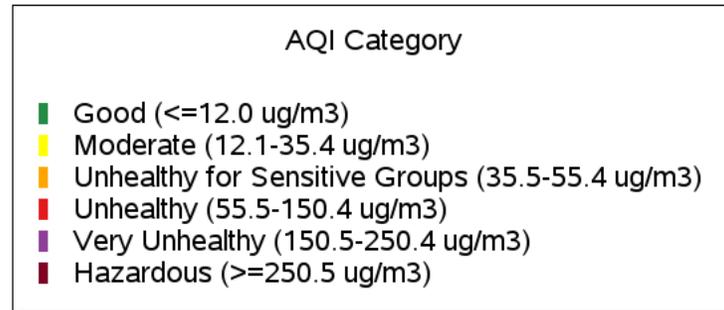
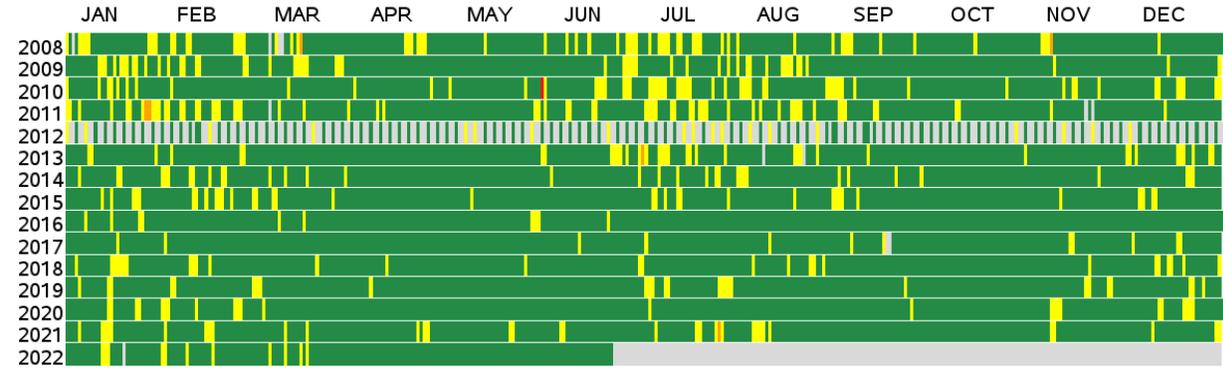
\*Three-year average of the annual 98<sup>th</sup> percentile twenty four-hour average.

# Daily average PM<sub>2.5</sub> concentrations, Rutland & Burlington

PM2.5 Daily AQI Values, 2008 to 2022  
Rutland, VT



PM2.5 Daily AQI Values, 2008 to 2022  
Burlington-South Burlington, VT



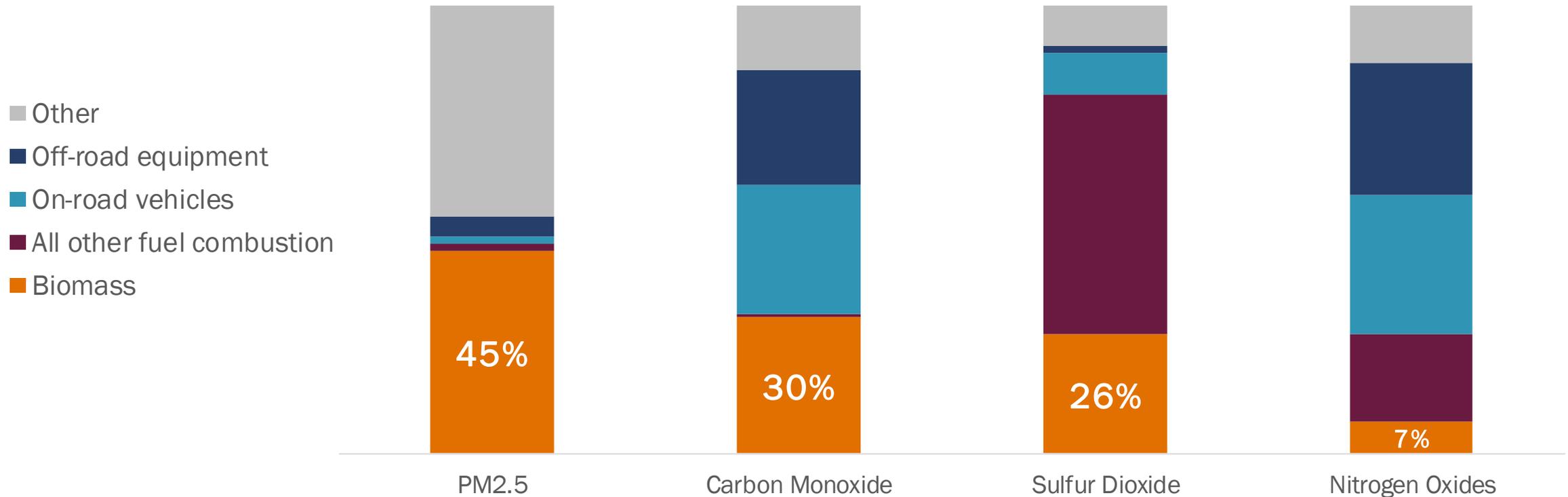
# There is no “safe level” of air pollution

## References:

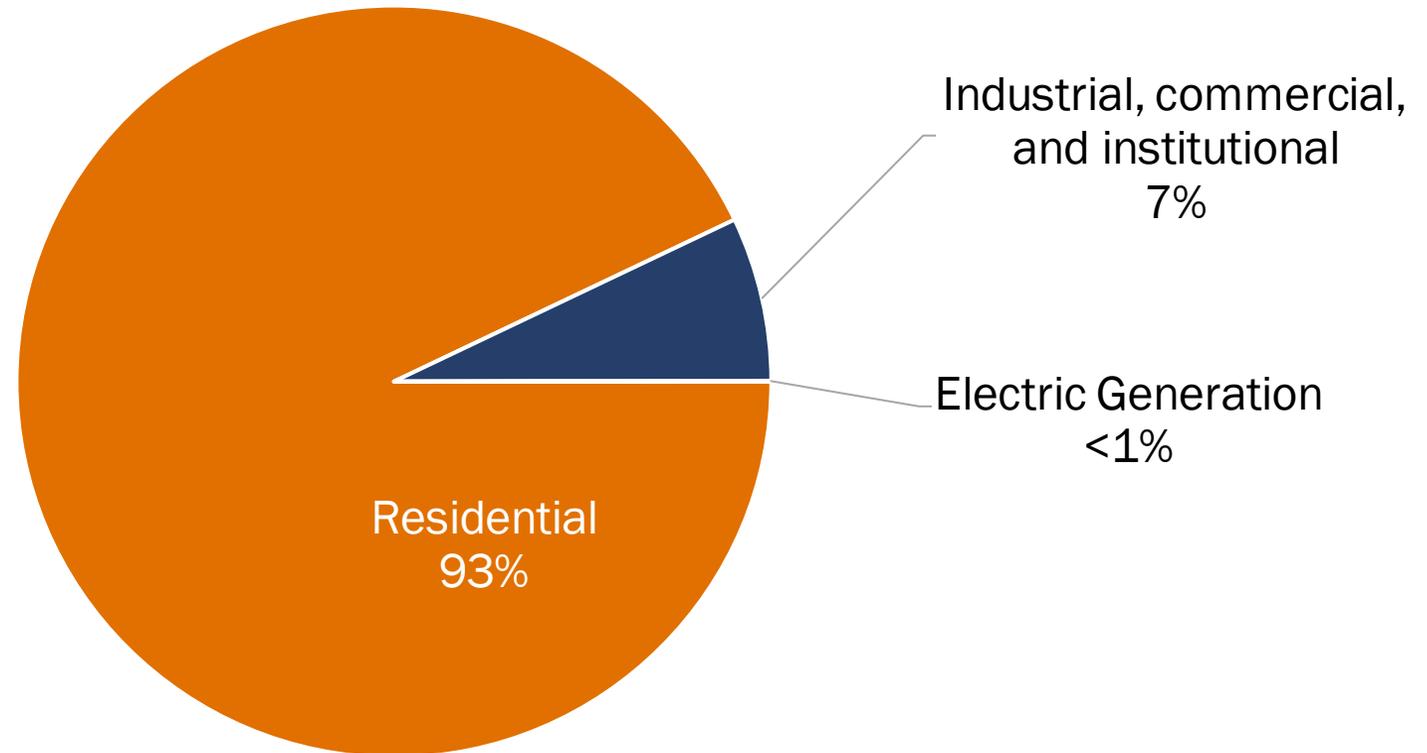
- Di Q, Wang Y, Zanobetti A, et al. 2017. Air Pollution and Mortality in the Medicare Population. *N Engl J Med* 373(26): 2513-22.
- Makar M, Antonelli J, Di Q, et al. 2017. Estimating the Causal Effect of Low Levels of Fine Particulate Matter on Hospitalization. *Epidemiology* 28: 627-34.
- Aung N, Sanghvi MM, Zembrak F, et al. 2018. Association Between Ambient Air Pollution and Cardiac Morpho-Functional Phenotypes. *Circulation* 138(20): 2175-2186.
- Wu X, Braun D, Schwartz J, et al. 2020. Evaluating the impact of long-term exposure to fine particulate matter on mortality among the elderly. *Science Advances* 6(29): 1-9.

# Major pollutant emissions sources in Vermont

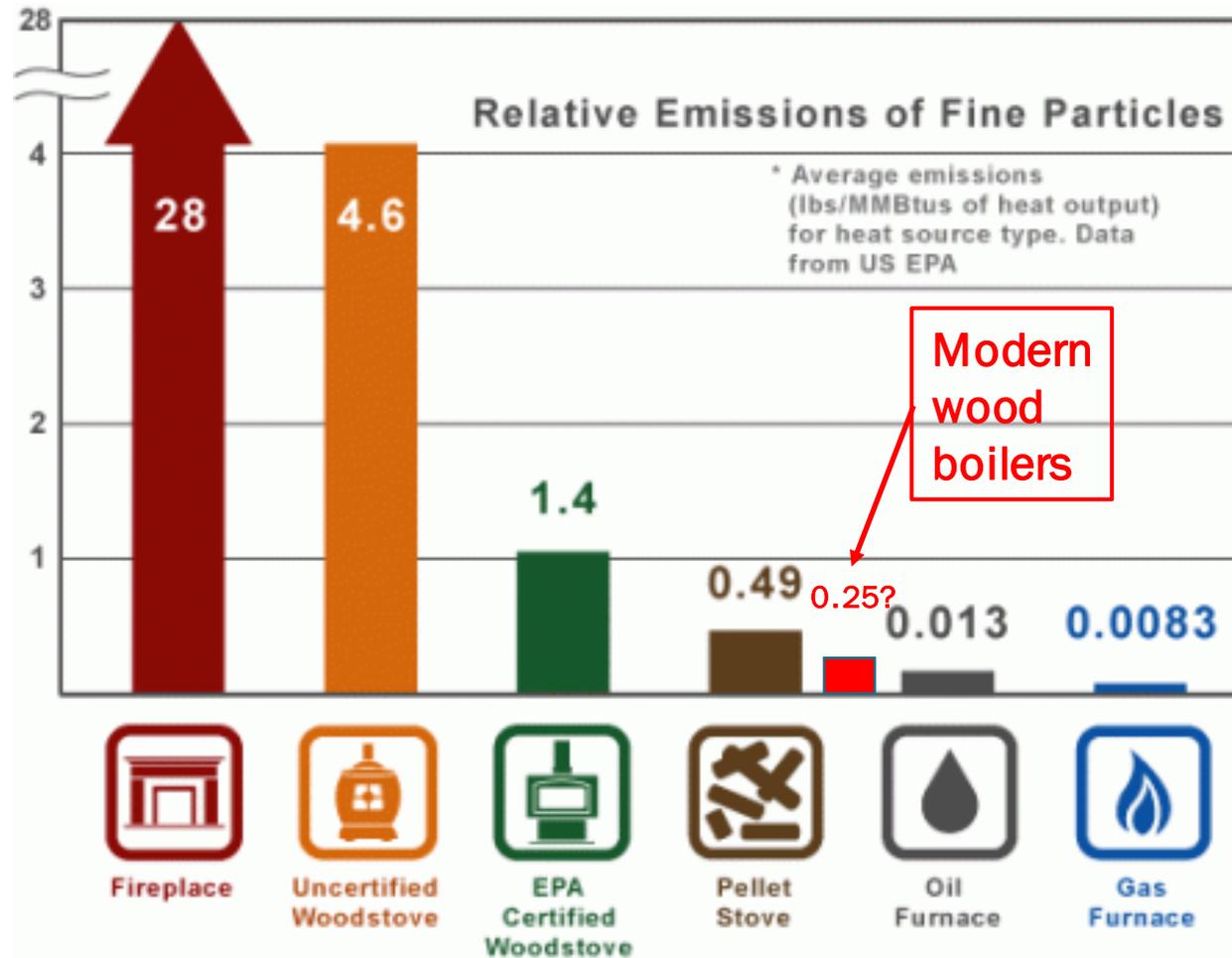
## Contribution to total emissions in Vermont, by pollutant



# Contributors to PM<sub>2.5</sub> biomass emissions in Vermont

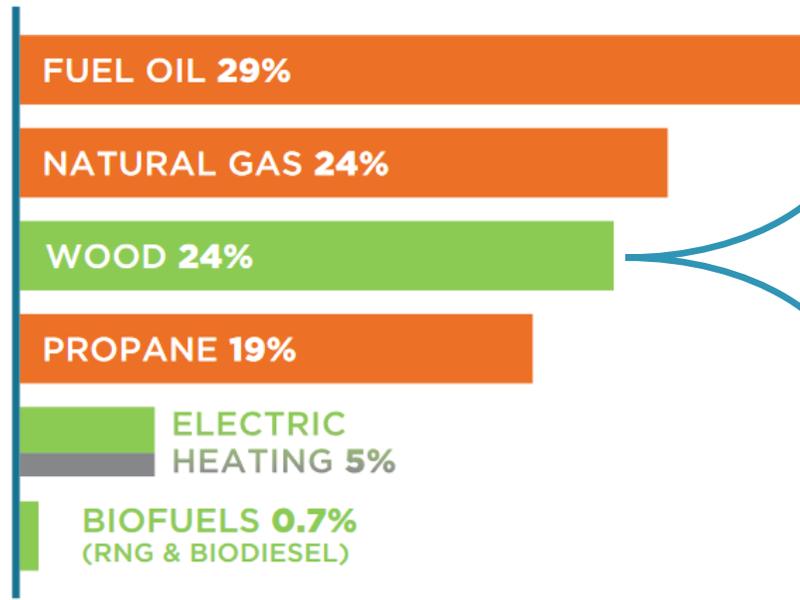


# Comparison of fine particle emissions by heating equipment

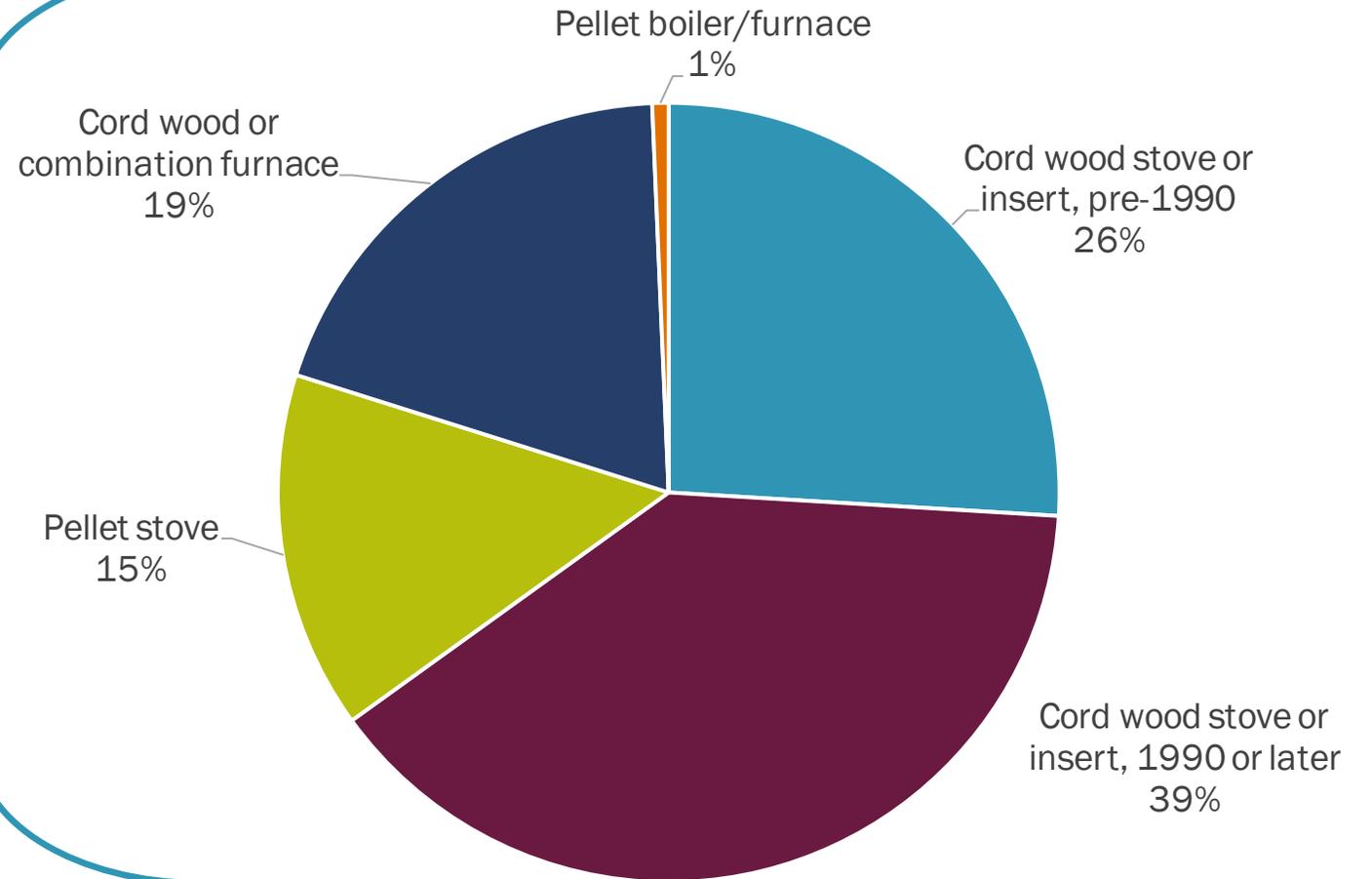


# Estimated distribution of residential wood heating devices by type

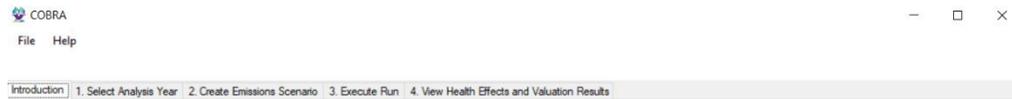
## Vermont heating energy sources, 2018



Source: EIA, 2020; Vermont Department of Public Service, 2020; Efficiency Vermont, 2020; Vermont Agency of Natural Resources, 2020



# EPA tools for estimating health impacts from emissions



**COBRA**  
Co-Benefits Risk Assessment  
Health Impacts Screening and Mapping Tool

## Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE)

**BenMAP Community Edition**

- Proven software that estimates the health impacts and economic value of changes in air quality.
- Powerful enough to perform a full-scale benefits assessment, but easy enough for beginners to use.
- Open-source to encourage community ownership.

**BenMAP**  
COMMUNITY EDITION

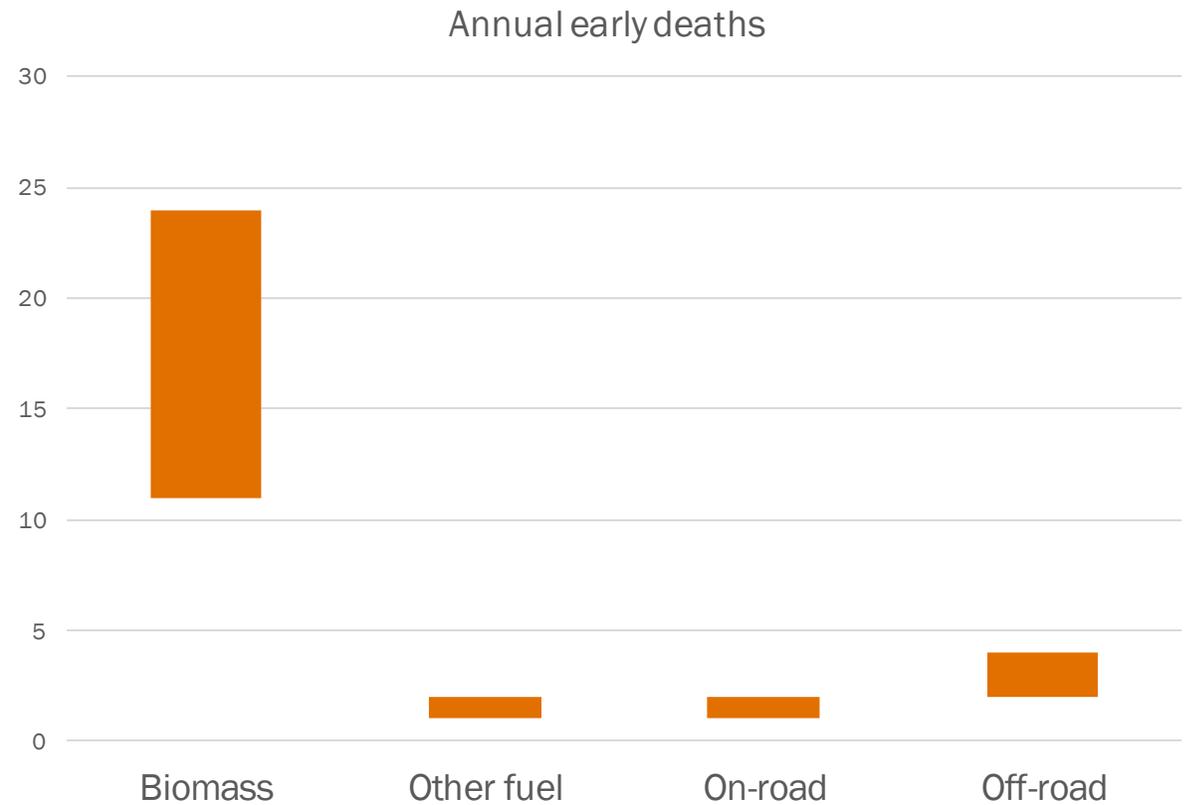
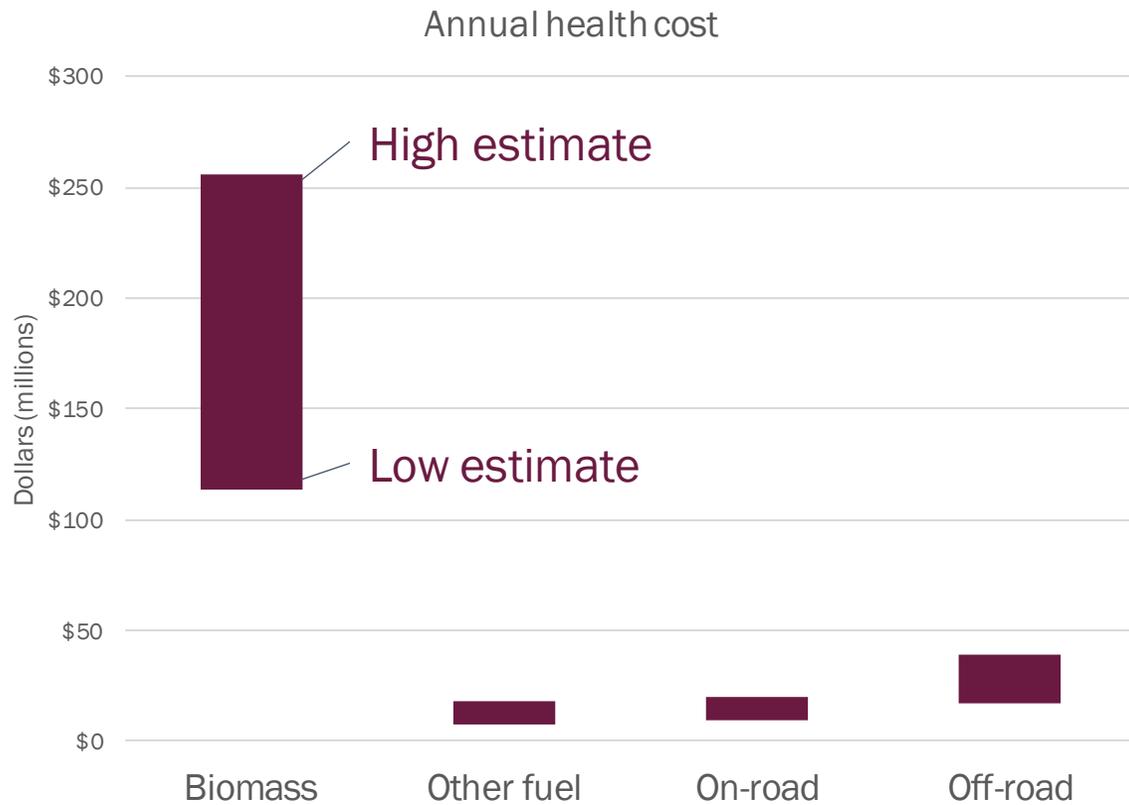
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BenMAP-CE enables users to load their own data or use pre-loaded datasets for the U.S. and China, including

- Air quality data
- Demographic data
- Economic values
- Concentration-response relationships

BenMAP-CE is an open-source computer program that calculates the number and economic value of air pollution-related deaths and illnesses. The software incorporates a database that includes many of the concentration-response relationships, population files, and health and economic data needed to quantify these impacts.

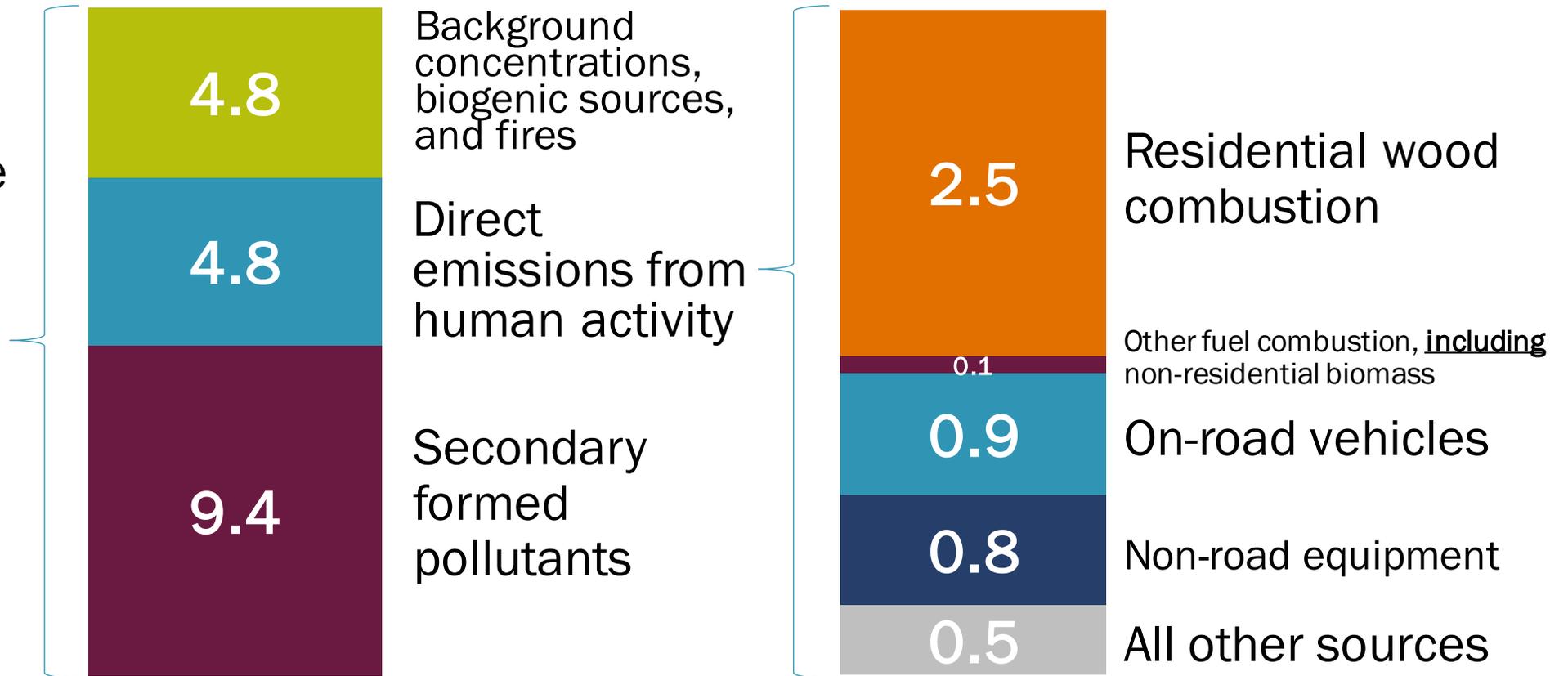
# Estimated health impacts associated with current emissions



# Cancer risk from toxic emissions in Vermont

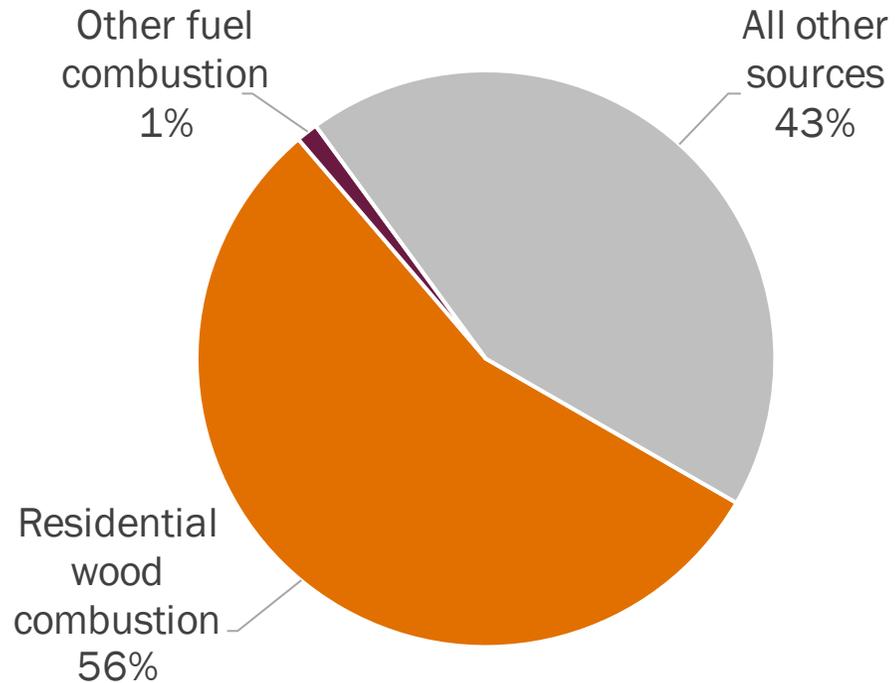
Vermont's total air toxic lifetime cancer risk:

**19 per million**

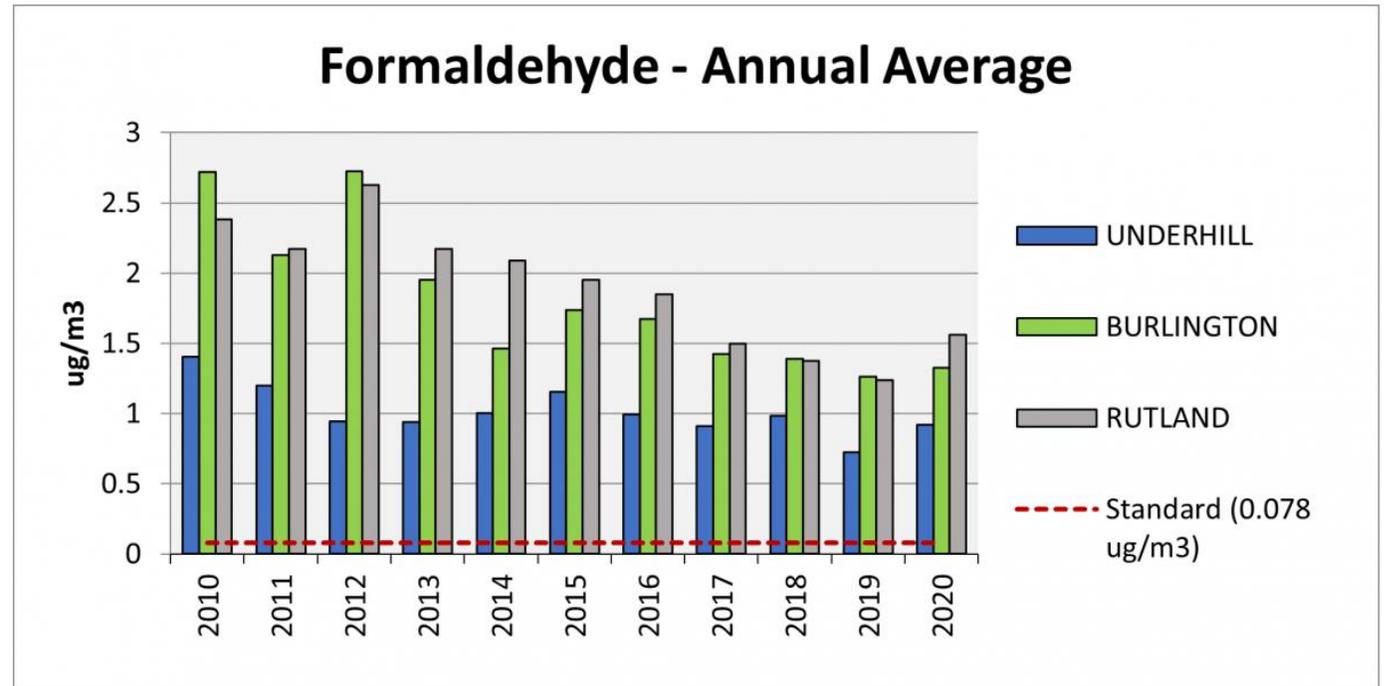


# Formaldehyde emissions & monitoring in Vermont

Breakdown of direct formaldehyde emissions from human activity



Formaldehyde - Annual Average



# Other health-related considerations

- Wide variability in emissions by fuel/stove characteristics, operating behaviors
- Indoor air quality impacts (mainly from outdoor air infiltration and ash removal)
- Higher localized impacts, particularly near residential sources
- Emerging health research on ultrafine ( $<0.1\mu\text{g}/\text{m}^3$ ) particles
- Impacts of wood boilers at schools

# Estimated health impacts of expanded wood heating in Vermont

2018 Roadmap for expanded wood heating in Vermont proposed:

- Increase wood heating from 21% to 35% of thermal load by 2030
  - Install 38,905 wood pellet stoves
  - Install 13,314 wood pellet or chip boilers

Estimated yearly health impacts\*:

- + 715 tons of PM<sub>2.5</sub> emissions
- + \$15 - \$35 million in health costs
- + 1 - 3 early deaths



## EXPANDED USE OF ADVANCED WOOD HEATING IN VERMONT

A Roadmap to Reach the Target of 35% of Vermont's Thermal Energy Demand with Wood Heating by 2030.

PREPARED FOR  
Vermont Working  
Lands Enterprise Board  
BY  
Renewable Energy  
Vermont and Biomass  
Energy Resource Center

# Options for reducing health impacts of wood heating

Annual benefits per 10,000 households	Improved wood storage, stove operation, etc.	Weatherization in homes that primarily heat with cord wood	Wood stove change-out (for 80% cord wood, 20% pellet stoves)	Wood stove change-out (for cold-climate heat pumps)
PM <sub>2.5</sub> reduction	?	450 tons	1,350 tons	1,825 tons
Health savings	?	\$10-\$22 million	\$28-\$64 million	\$38-\$85 million
Early deaths avoided	?	0-2	2-5	4-8
Additional health benefits for occupants		Improved indoor air quality, moisture control, reduced thermal stress, more...		Hot weather resilience

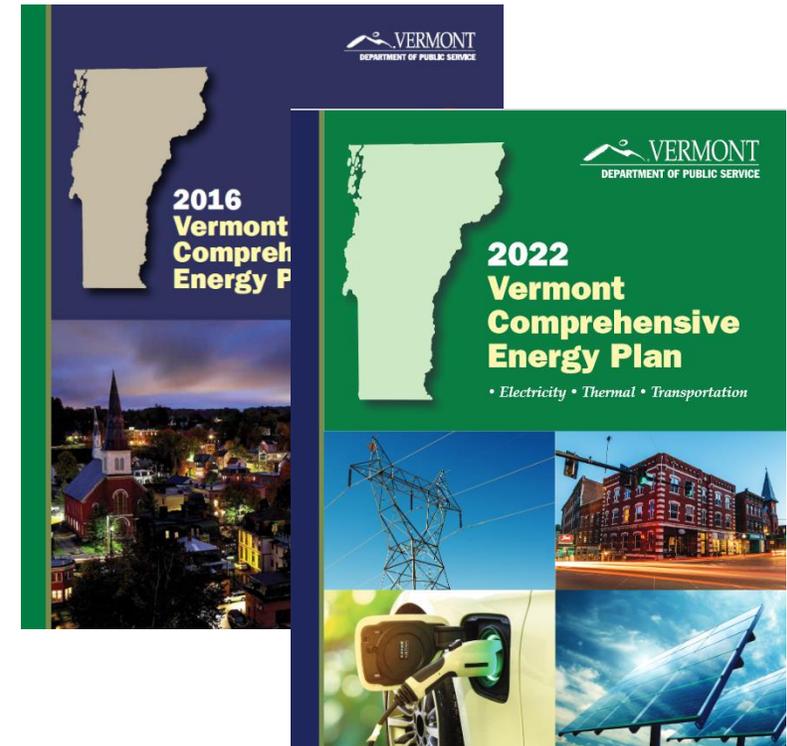
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# Health Impact Assessments

2016 Comprehensive Energy Plan acknowledged (and the 2022 Plan reaffirmed) the importance of “assess(ing) the health impacts of our energy systems”

- Commonly referred to as **Health Impact Assessment**
- Assess expected impacts based on scientific evidence, feedback from public and experts
- Identify and avoid/mitigate potential negative health impacts
- Specifically focus on disparate impacts to populations of concern
- Evaluate tradeoffs and alternatives to make informed decisions





**Thank you!**

**Let's stay in touch.**

**Email:** [ClimateHealth@vermont.gov](mailto:ClimateHealth@vermont.gov)

**Web:** [www.healthvermont.gov](http://www.healthvermont.gov)

**Social:** [@healthvermont](https://twitter.com/healthvermont)